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Parameterisation by combination of different levels of process-based model physical complexity

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Hydrological models can be viewed to exist along two dimensions, one between the ideals of “physically based” and “conceptual”, the other being the degree of correct process basis. The more advanced physically-based descriptions of “surface” processes may be often justified where there is sufficient information, and there are examples of success in the application of these models. However, physically-based descriptions of the subsurface processes do not necessarily lead to realistic simulations of sub-surface hydrology because of extraordinary difficulties in fulfilling the information requirements. In sparsely gauged regions, there are additional difficulties in fulfilling information requirements for surface hydrology aspects of physically based models. To resolve this dilemma, more conceptual models have been developed for conditions of poor, both surface and subsurface, data availability. Often such models are not able to correctly incorporate new process understanding or measurement techniques and rely on heavy calibration of parameters because they have poor process conceptualizations. But when models properly conceptualize the processes, not only are parameters relatively stable over time and space, but they can incorporate new process information and measurements to improve streamflow prediction. These process based models have great potential for ungauged prediction.

For vast regions of the world with sparse monitoring networks like much of Russia or Canada, detailed catchment data only exists in small-scale research basins. Process based model parameterisations that are confirmed and refined in this basins can be applied in hydrologically similar regions. Parameters and outcomes developed using physically-based models can be used to estimate the parameters of more conceptual process models. These conceptual models may be then regionalized and used in large scale applications or extended to time periods when data availability is sparser. This approach is demonstrated here.

Hydrograph is a robust Russian process-based model where the processes have a physical basis and certain strategic conceptual simplifications that give it the ability to be applied successfully in many parts of the world. It has an appropriate physics and level of model complexity for a remote, sparsely gauged region such as northern Canada and has ability to use many parameters that can be observed in the field, but some of these parameters are not normally measured. The Cold Regions Hydrological Modelling Platform (CRHM) is a modular modelling platform that contains a range of process modules from conceptual to highly physically-based. These modules can be combined to create physically based hydrological modules or run individually or in small combinations to describe specific aspects of the hydrological cycle.

In applying Hydrograph to Wolf Creek Research Basin in the Yukon Territory, Canada three areas of surface parameter uncertainty were identified relating to: i) spatial variability of snow accumulation due to drifting, ii) estimating the amount of infiltration of meltwater into frozen soils, iii) relating evapotranspiration to air temperature, humidity and solar radiation. CRHM has physically based process modules for calculating blowing snow transport and redistribution, infiltration into frozen soils and actual evapotranspiration from unsaturated surfaces and vegetation. These modules have been verified in Wolf Creek basin. They were used to develop the information needed to set Hydrograph parameters relating to the coefficient of variation of snow water equivalent, the infiltration to the mineral soil layer during snowmelt and the effective temperature and vapour pressure deficit for evapotranspiration. The result is a more confident application of Hydrograph to this basin and parameters that have a greater physical meaning which makes them more robust and therefore amenable for regionalisation. The use of these parameters in upscaled application of Hydrograph to the Yukon River is then explored.